

**Navy Personnel Research, Studies, and Technology Division
Bureau of Naval Personnel (NPRST/BUPERS-1)**

Millington, TN 38055-1000

NPRST-TN-07-8

July 2007

Matching Sailors to Positions Based on Skill

Janet H. Spoonamore, Ph.D.
H. James Simien, M.S.
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Reviewed, Approved, and Released by
David L. Alderton, Ph.D.
Director

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Navy Personnel Research, Studies, and Technology
Bureau of Naval Personnel
5720 Integrity Drive
Millington, TN 38055-1000
www.nprst.navy.mil

REPORT DOCUMENTATION PAGE					<i>Form Approved OMB No. 0704-0188</i>	
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16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON	
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Foreword

This report provides analysis of alternative approaches for matching Sailor's skill characteristics to position requirements. Factors such as pay band, job type, required knowledge, skill, and abilities (or pay grade, rating, & Navy Enlisted Classifications [NECs]) are used as the basis for matching. By varying the weighting of these individual factors, alternative algorithms are developed. The results of matching using these algorithms have been evaluated by technical experts. Recommended algorithms were developed.

Funding for this project is provided through the Integrated Sailor/Marine Career Management System (IS/MCMS), a 6.2 applied research project funded by the Office of Naval Research (ONR) under the Future Navy Capability ACQUIRE Program.

The authors wish to thank the functional sponsor for the Sea Warrior Person-to-Position Mapping project, CDR T. Scott Barbier; Robert Duley; Ann Stewart; LT Thomas Ball; Dan Petty; Kathryn Bailey; Robert Oren; Walter Cleighton; Jeff Fox; and CWO Mike Shellenberger for their support, leadership, and guidance. The authors would also like to thank Mr. Kelysey Henderson and Dr. Katrina Ricci for their input and support regarding training assessment. In addition, N10 staff, Mr. Ilia Christman, Mr. Tony Cunningham, Mr. Ed Bres, and Mr. Steve Cylke provided keen insight and helpful comments and suggestions throughout this research effort.

DAVID L. ALDERTON, Ph.D.
Director

Executive Summary

Background

The U.S. Navy in developing its new Career Management System—Interactive Detailing—continues to improve the Navy’s assignment process. The Navy plans to implement tools such as numerical optimization, which take into account multiple competing factors such as improving readiness, improving Sailor satisfaction, and at the same time, improving cost efficiencies. One key factor in matching Sailors and jobs is based on skill characteristics. The skill factor is tied directly to readiness, and in some ways, indirectly, to Sailor satisfaction. The purpose of this study is to develop alternative algorithms for matching persons to positions based on skill, evaluate these approaches, and recommend those approaches achieving the desired results for the Navy.

Problem

The Navy has not established specific business rules for comparing candidate Sailor credentials against position requirements. Activity Manning Documents (AMD) describe position requirements, based on rating, pay grade, Navy Enlisted Classifications (NECs) (and ultimately job type and pay band). Comparing personnel on board against AMD requirements, one observes disparities in the actual versus “required” pay grades and NECs for the various technical communities, especially those positions which have multiple NECs. Given these three factors, rating, pay grade and NECs, it is inevitable that various approaches are taken in comparing Sailors’ credentials against position requirements. One set of approaches emphasize that pay grade is more important; while others emphasize NECs. Another set of approaches calculate individual Sailor-position fitness scores; others compare fitness at the aggregate level. There exist various approaches that use sequential matching which is dependent on the order in which the matches are made, and therefore do not produce reliable, repeatable, or accurate results. The use of any of the aforementioned approaches may lead to inconsistent and/or inaccurate results in making assignments, identifying training needs, and generating requisitions for vacant positions.

The process of matching across multiple factors related to skill (rating, pay grade and NEC) is the notion of weights, or levels of importance, placed on these various factors. Currently, no explicit weights have been specified for the factors considered in the distribution and assignment process for any given set of Sailors and jobs. The result is that the specific value of these weights will vary across detailing communities, detailers, or even individual assignments. The establishment and incorporation of a detailed weighting schema is crucial in implementing a valid assignment scoring algorithm in the distribution and assignment process. The same algorithm should also be used consistently throughout the Manpower, Personnel, Training, and Education (MPTE) enterprise.

Further complicating this matching process is the way in which matches are made across a group of positions based on an available pool of candidate Sailors. The current detailing and requisition generation process uses a sequential approach in matching which leads to poor results with respect to the various measures of effectiveness (MOEs). Early matches often preclude otherwise superior later matches from being made. The recommended method to use in matching a group of Sailors and positions is based on mathematical optimization, the purpose of which is to guarantee the best possible match—not just for the individual, but Navy-wide.

Objective

There are numerous ways to match Sailors to jobs, based on skill. First consideration may be based on rating or job type (e.g., Boatswain's Mate [BM], Electronics Technician [ET]). A second consideration may be pay grade or pay band. A third consideration may be earned NECs, or ultimately more detailed knowledge, skills, and abilities. Questions arise regarding rating or job type. Can ratings or job types which are similar be cross-matched? Must the rating or job type match exactly or are there degrees of match ranging across a continuum? Are there degrees of match based on the individual's skill assessment, training scores, or job performance metrics? Are the factors: job type, pay band, and specific required knowledge, skills and abilities of equal importance, one to each other? Is it satisfactory to match on primary skill, but not on secondary, tertiary skill? What is the relative importance of NECs, primary versus secondary? Is it reasonable to match a position's required primary and secondary NEC's to two Sailors, i.e., the primary NEC to one Sailor's earned NEC and the secondary NEC to a different Sailor's earned NEC? Or must each position be matched to one and only one individual? Is there a single algorithm that uses these factors which adequately describes the matching across all job types? Or across all pay grades? Can pay grades be banded into apprentice, journeyman, and master? Can lower pay grade personnel match to higher pay grade positions? The objective of this report is to consider various matching algorithms, taking into consideration input from technical experts, and determine those which are (a) the most accurate and (b) the most efficient and practical to implement in the Navy context. This obviously requires investigating and establishing appropriate metrics for accuracy, efficiency, and practicality. The results of this report provide the basis for future implementation of skill matching algorithms.

Approach

The analysis of alternative algorithms for skill match began with a review of various algorithms and their application to different points in the distribution and assignment process, including requisition development, assignment, and management reporting. It is pointed out that matching using simultaneous optimization techniques is preferable, based on outcomes, versus using sequential matching runs. The Person-to-Position (P2P) pilot results are analyzed, as well as operational expert input. This report provides an analytical discussion of the alternative algorithmic approaches which that show the most promise for Navy implementation.

Conclusions and Recommendations

The recommended algorithm for matching Sailors to positions is based on development of a scoring rule which calculates an overall skill score between zero and 100 for each position and each candidate Sailor. This score is an objective measure of qualitative factors: job type, pay band, and knowledge, skill and abilities (rating, pay grade, NECs). There is *not* a “one-size-fits-all” algorithm for calculating Sailor-position skill scores that makes sense across all communities. However, within communities, oftentimes there is a single scoring algorithm. Basic eligibility for a position varies across job types or ratings. Some allow specific pay grades substitutions; others do not. For some communities, pay grade as a factor, is more important than NECs. For others (e.g., Hospital Corpsman [HMs]), pay grade is not as important as NECs.

NECs are complex to match. First, each position in the Activity Manning Document (AMD) may have up to two NECs, primary and secondary. Each Sailor, in his inventory, has up to five earned NECs: first, second, third, fourth, and fifth. Detailers, when detailing a Sailor to a position, specify up to two specific Distributable NECs (DNECs) taking into account training en route.

Important to the matching process is the method used for matching, assuring that accurate matches are made. In the manual matching process, one usually uses what is known as “sequential” matching, whereby one goes through the sequence of positions, one by one, matching available Sailors. When a Sailor and position are matched, they are taken out of consideration in later matches. The problem with this type of match (sequential matching) is that different orders of matching produce different results. An improved way to match is using “optimized” matching which simultaneously, using numerical optimization techniques, considers all possible combinations of matches arriving at the best possible match. It is recommended that whenever possible, optimized matching be used when matching Sailor and positions, based on skill match, as well as other possible factors.

The recommended skill match algorithm is based on a formula that weights the ingredient factors in terms of importance. The weights vary from 0 (zero) to 1 and add to 1 (i.e., are normalized). The factors that are considered are rating, pay grade, and NECs. Ultimately, when future taxonomies characterizing required knowledge, skills and abilities become available, these data elements will be used in matching.

The Navy’s algorithm for matching positions and Sailors based on skill must meet four important criteria:

1. The algorithm or scoring rule must provide an accurate, valid, objective measure of required skill versus Sailor’s credentials.
2. Basic Go/No Go eligibility must be taken into account.
3. The algorithm should be consistent across the MPTE enterprise, throughout the MPTE Supply Chain process.
4. The matching process of Sailors to positions must be based on optimized matching, not sequential matching.

5. Even though there is no “one-size-fits-all” algorithm for the skill match calculation, there is a “one-size-fits-all” *formula* that tailors the algorithm based on the specifics of the position characteristics. First, it is essential that the skill match be interpreted as a score showing quantitatively the degree of the skill match of the Sailor to the specific position. This score should be an objective score that decomposes into the weighted factors making up the components of the score. See general formula below for skill score, S :

$$S = \alpha \text{ ratingscore} + \beta \text{ paygradescore} + \gamma \text{ NECscore}$$

$$\text{where } \alpha, \beta, \gamma \geq 0, \text{ and } \alpha + \beta + \gamma = 1$$

Using this general formula, one can modify the weighting on factors for rating, pay grade, and NEC matching so that the exact desired outcome is achieved in the overall match. A minimum score would likely be required for a Sailor to be considered eligible for a particular position. Similarly, algorithms which score each of these three individual matching factors—rating, pay grade, and NEC—can be characterized as complex formulations which take into account needed specificity. A particular factor (e.g., paygradescore) may be calculated using a detailed algorithm, perhaps based on exact match, closer matches, etc. Further, if, for a specific position, pay grade is not an important factor, γ , the weighting on pay grade score, may be set to 0. Alternately, for a specific position (e.g., a chief position) NECs are not as important as pay grade. Then, the weightings may be assigned accordingly (e.g., $\beta = .75, \gamma = .25$).

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Introduction

The Navy's Manpower, Personnel, Training, and Education (MPTE) enterprise performs Sailor-job matching. Matching considers basic eligibility such as security clearances, sea/shore rotation, appropriate timing, and other factors. Matching also involves qualitative factors: level of skill match, on-time arrival, Permanent Change of Station (PCS), and training costs. This study attempts to characterize and improve the skill match component of the overall Sailor-job matching process.

The Navy's Activity Manning Documents (AMDs) describe the required personnel positions in terms of ratings, pay grades, and NECs (ultimately job types, pay bands and future taxonomies characterizing required knowledge, skills and abilities) needed to man the Navy fleet and shore commands. Requirements expressed in the AMDs are used at three levels within the MPTE enterprise.

1. Navy community management addresses development of Sailor's careers to meet the overall manning requirements expressed in the AMDs at an aggregate level. This involves characterizing development points from recruitment to separation by targeting goals for recruitment, training, sea/shore rotation, advancements, conversions to other job types, and retention. Community management responsibility ensures availability of the right personnel inventory of each rating's pay grades and associated NECs on an aggregated basis.
2. Navy's monthly requisition development process involves identifying all required positions, taking into account Sailors who will be transitioning (rotating to another position, separating, or retiring) to arrive at a compilation of required vacant positions. These activity positions, characterized by rating, pay grade, and NECs are advertised during the monthly requisition cycle.
3. The third critical process is the monthly assignment process whereby detailers (i.e., those charged with making Sailor assignments), those who work with Sailors and Commands in making the actual assignments, consider the requisitions for which they are responsible, review and interact with Sailors and Commands and, based on the specific required pay grades, NECs, and Sailor preferences proceed to match Sailors to jobs. Detailers take into consideration other factors besides skill match in order to make assignments (e.g., on time arrival, moving costs, requisition priority, Sailor preference, and others).

The analysis for this study poses questions that must be addressed when defining business rules for accurately calculating skill matches between positions and Sailors. The analysis goes further in providing the mathematical formulation and relevant weighting factors.

This section establishes the context of skill matching within the current distribution and assignment processes. The following section on *Skill Measure of Effectiveness* shows and analyzes an alternative algorithm with data-based examples. Next is the section on *Optimized Matching Versus Sequential Matching* that argues the importance of optimization in achieving accurate matching results. The section on *Person-to-Position Pilot* explains and analyzes a proposed algorithm developed by Navy

stakeholders and subject matter experts. A *Scoring Rule for Skill Match Based on Weighting Factors* argues for a scoring rule approach to matching and provides pseudo-code, specifically for the business rules laid out by the *Person-to-Position Pilot*. Finally, the section *Recommended Person to Position Matching Algorithm* details the development of the recommended algorithm using pseudo-code.

References are provided. A Glossary of Terms used to prepare this report is provided in the Appendix.

Skill Measure of Effectiveness (MOE)

Factors available to assess skill match include rating, pay grade, and NECs and ultimately, job type, pay band, and future taxonomies characterizing required knowledge, skills, and abilities. Job requirements showing rating, pay grade, and primary and secondary NECs are maintained in Activity Manning Documents (AMDs).

Job Advertising and Selection System (JASS) Career Management System (CMS) – Skill Score

JASS-based CMS (JCMS) functionality provides a skill score for comparing Sailor rating, pay grade and NECs to requisition requirements (*Job Advertising and Selection System (JASS) Career Management System (CMS) Spiral 2 Functional Requirements*, 2005). As noted, the skill score takes into account three factors: rating, pay grade, and NECs. (See the Table 1)

Table 1
JCMS skill match

Attribute	Weight
Rating	41
Pay grade	
Match	39
(+/- 1)	30
(> 1)	0
NEC	See below

Table 2
NEC match weighting

Primary NEC	Secondary NEC	Weight
Match	N/A	20
Match (dual coded)	Match	20
Match (dual coded)	No Match	10
No Match (dual coded)	Match	10
N/A	N/A	20

Note that the sum of the rating, pay grade, and NEC weight scores gives the overall skill score, a maximum possible score of 100. This calculation is translated into a red, yellow, green score on the Sailor's job listing screen. Each job shown gives the Sailor a quick review of his skill match to the particular job. Specifically:

- Green 100
- Yellow 69–99
- Red ≤ 68

Note, in order to get a “green” score of 100, all matches must be exact (i.e., perfect rating match, perfect pay grade match, and required NECs must be met). For a “yellow,” a score of at least 69, the match must include the same rating and within the “one up” or “one down” on the pay grade match. Note, using this scoring rule, an Electronics Technician First Class (ET1) Sailor would get a “yellow” compared against a Chief Electronics Technician (ETC) position. A fundamental question would be whether this scoring rule captures the complexity involved in matching positions and Sailors, based on skill match. Note that this business rule requires strict compliance to gain a “green”. “Yellow” can only be attained by matching rating and not off by pay grade more than one; “red” shows rating mismatch or pay grade mismatch greater than one.

Matching Individuals to Positions

To illustrate the process of matching individuals to positions, several examples are shown. The examples shown are taken from actual Sailor and position data. The examples, Tables 3–7, contain positions (rating, pay grade [PG] and required NECs [Req NECs]) and Sailors (rating, pay grade, and NECs). Positions have at most two required NECs: primary and secondary. Note that Sailors' records contain up to seven possible NECs: two distributed NECs and five earned NECs. The notation in Tables 3–7 show “Sailor” columns labeled “EN1”, “EN2,” or “DN1” that refer to a Sailor's primary Earned NEC, secondary Earned NEC or primary Distributable NEC. Specifically, Table 3 example below shows 14 Gas Turbine Systems Technician–Mechanical (GSM) positions. The pay grade 3 and pay grade 4 positions do not have required NECs. The pay grades 5, 6, and 7 positions each have one required NEC. Note that some Sailors show NECs of “oooo,” called “quad zero.” These Sailors do not have any earned NECs. Earned NEC

must be attained through formal school or on-the-job-training (OJT), which is approved by the commanding officer. Distributed NECs (DNEC) are specified by the detailer at the time of assignment, identifying the requisition NECs to which the Sailor is assigned. Understandably, given that Sailors take training en route to an assignment, the electronic records sometimes lag in showing credit for earned NECs. An example of this discrepancy may be the GSM1 DNEC 4142 which does not appear as an earned NEC (ENEC).

Example Skill Matches—Reasonably Good Match

One may consider the matching shown below to be reasonable, in that pay grade and NECs match fairly well, although not perfectly. Although each required NEC is met by one of the Sailors' DNECs or ENECs, note there are several pay grade mismatches. One could argue that it may be better to give higher weight to pay grade highest followed by NECs. However, this results in several NEC mismatches. This example shows the importance of specifying weighting. Is pay grade more important or is the NEC more important? And to what extent? These important questions can be explored and answered from a combination of conceptual and empirical perspectives.

Table 3
Example skill match—Reasonably good match

Position			Sailor					
Rating	PG	Req NECs	Rating	PG	DN1	EN1	EN2	EN3
GSMFN	3		GSMFN	3		0000		
GSM3	4		GSM3	4		0000		
GSM3	4		GSM3	4		0000		
GSM3	4		GSM2	5		4541		
GSM3	4		GSM2	5		0000		
GSM3	4		GSM3	4		0000		
GSM3	4		GSM3	4		0000		
GSM2	5	4126	GSM3	4	4126	4126		
GSM2	5	4126	GSM1	6	4126	4129	4126	9585
GSM2	5	4142	GSM1	6	4142	4222		
GSM2	5	4222	GSM1	6	4222	0000	9585	
GSM1	6	4126	GSM1	6	4126	4126	4222	
GSM1	6	4140	GSM2	5	4140	0000	9545	
GSMC	7	4126	GSMC	7	4126	4126	9585	

Example Skill Match—Somewhat Poor Match

Matching only one of the required NECs for a position that has two required NECs may be considered a somewhat poor match. This example illustrates that the Fire Controlman Second Class (FC2) position requires primary and secondary NECs; yet, only the primary NEC 1120 is met. The NEC 9527 is not met.

Table 4
Example skill match—Somewhat poor match

Position				Sailor							
Rate	PG	Req NECs		Rate	PG	DN1	DN2	EN1	EN2	EN3	EN4
FC2	5	1120	9527	FC2	5	1120		1120			
FC2	5	1121		FC2	5	1121		1164	1121		
FC2	5	1136		FC1	6	1136		1332	1334	1169	9502
FC2	5	1136		FC2	5	1136	9575	1110	9575		
FC2	5	1169		FC2	5	1121	1169	1169	1121		
FC1	6	0334		FC1	6	1121		1121			
FC1	6	1121		FC2	5	1121		1145	1121		
FC1	6	1136		FC1	6	1136		1136	1334		
FCC	7	1120		FCC	7	1120		0334	1120		
FCC	7	1332		FCC	7	1332		1332	1136		

Example Skill Match – Very Poor Match and Improvements

In Table 5 one observes that the ETC position (shaded) is filled by pay grade 4 Sailor—a violation of commonly accepted eligibility rules. Also note that the chief petty officer fills a pay grade 5 position.

Table 5
Example skill match—Very poor match

Position				Sailor							
Rating	PG	Req NECs		PG	DN1	DN2	EN1	EN2	EN3	EN4	EN5
ET3	4	1406	9604	6	9604		9604	1480	1579	1493	1486
ET3	4	1410	1430	5	1430	1410	1415	0000			
ET3	4	1420	1486	4	1486	1678	1424	1678	1486		
ET3	4	1425	9605	5	9605		1430	1410	9605	1420	
ET3	4	1430	1406	4	1425		1410	1452	1428	1425	1420
ET3	4	1571	1591	5	1571		1571	1420	9527		
ET3	4	9612	1678	4	9612		9612	1471			
ET2	5	1486	1420	5	1486		1486	1413			
ET2	5	1571	1471	6	9602	1571	9602	1572			
ET2	5	1678	9612	7	1678		1678	9607	9605	1486	1468
ET2	5	9604	1424	6	1678	9604	1599	9604	1678	9585	
ET1	6	9605	1425	6	9605	1504	9605	1424	1504	1465	9608
ET1	6	9608	1410	4	1486	9608	1486	9608			
ETC	7	9608	1424	4	1424	9612	9612	1424			

Now consider changing the following rematches (shaded) in Table 6 below:

Match ETC position with the chief petty officer (CPO), even though NECs do not match.

Match ET2 position with ET3 Sailor; note 1678 primary NEC matches.

Match ET3 position with ET3 Sailor; note NECs do not match.

Table 6
Example skill match – Improvement

Position				Sailor								
Rate	PG	Req NECs		Rate	PG	DN1	DN2	EN1	EN2	EN3	EN4	EN5
ET3	4	1406	9604	ET1	6	9604		9604	1480	1579	1493	1486
ET3	4	1410	1430	ET2	5	1430	1410	1415	0000			
ET3	4	1420	1486	ET3	4	1424	9612	9612	1424			
ET3	4	1425	9605	ET2	5	9605		1430	1410	9605	1420	
ET3	4	1430	1406	ET3	4	1425		1410	1452	1428	1425	1420
ET3	4	1571	1591	ET2	5	1571		1571	1420	9527		
ET3	4	9612	1678	ET3	4	9612		9612	1471			
ET2	5	1486	1420	ET2	5	1486		1486	1413			
ET2	5	1571	1471	ET1	6	9602	1571	9602	1572			
ET2	5	1678	9612	ET3	4	1486	1678	1424	1678	1486		
ET2	5	9604	1424	ET1	6	1678	9604	1599	9604	1678	9585	
ET1	6	9605	1425	ET1	6	9605	1504	9605	1424	1504	1465	9608
ET1	6	9608	1410	ET3	4	1486	9608	1486	9608			
ETC	7	9608	1424	ETC	7	1678		1678	9607	9605	1486	1468

NEC versus Pay grade—Poor Match

A mismatch may occur due to too heavy an emphasis on NEC, such as the example below. Here in Table 7 the Chief Operations Specialist (OSC) job is matched to an Operations Specialist Second Class (OS2), seemingly because the 0310 NEC matches. Navy business rules disallow lower bands (i.e., journeyman filling master level) going into upper level positions, especially the chief petty officer position. An algorithm that uses such eligibility criteria would prevent this kind of mismatch. Another point shown in the example below is that Sailor NEC data may not be accurate. Note that the 0310 NEC is required for most of the OS jobs. This particular NEC may be earned by completion of formal training or OJT awarded with one year operational experience on the specific platform, as qualified watch station, or based on commanding officer recommendation. Given that so many Sailors have advanced NECs, it is likely that some are also watch station qualified for the 0310; however, this is not reflected in the records.

Table 7
Example skill match—NEC versus pay grade

Position				Sailor								
Rate	PG	Req	NECs	Rate	PG	DN1	DN2	EN1	EN2	EN3	EN4	EN5
OS3	4	0310		OS3	4			0000				
OS3	4	0310		OSSN	3			0000				
OS3	4	0310		OSSN	3			0000				
OS3	4	0342	0310	OS3	4			0201	0170			
OS3	4	0342	0310	OS2	5	0342		0318	0342	9575		
OS2	5	0318	0310	OS2	5			0348	0000			
OS2	5	0318	0310	OS1	6	0318		0318	0348	9585		
OS2	5	0318	0310	OS1	6	0318		0318	9545	0342		
OS2	5	0324	0310	OS1	6	0310	0324	0324	0310			
OS2	5	0324	0310	OS2	5			0348				
OS2	5	0324	0310	OS2	5	0324		0324	0334	0342	0311	
OS2	5	0334	0310	OS2	5	0334		0326	0334	0342	0348	
OS2	5	0334	0310	OS2	5	0334		0334				
OS2	5	0334	0310	OS2	5	0334		0334				
OS2	5	0342	0310	OS2	5	0342		0342	0302			
OS2	5	0348	0310	OS2	5	0348		0201	0348	0336		
OS2	5	0348	0310	OS2	5			0326				
OS2	5	0348	0310	OS1	6	0318	0348	0350	0318	0342	0348	0310
OS1	6	0319	0326	OSCS	8	0319		0350	0319	9595	0310	0311
OS1	6	0326	0310	OS2	5	0310		0310				
OS1	6	0326	0350	OS2	5	0326		0000				
OSC	7	0310		OS2	5	0334	0310	0334	0201	0310		

One can observe the complexity of matching, based on rating, pay grade, and NECs. Adding more granular data based on more detailed knowledge, skills and requirements could further complicate the matching process—but it may also improve it compared with operating on more limited information. Also note that these examples—matching individual Sailors to individual positions—do not address a possible approach that considers matching multiple points of overlap between positions and Sailors. For example, a specific position’s primary and secondary NEC requirements may be fulfilled by two Sailors. Or similarly, a specific Sailor may be assigned, based on earned NECs, to two separate positions that match the required NECs.

Optimized Matching versus Sequential Matching

Sequential matching is defined as the process of matching a given set of positions and candidates, starting at the first position, choosing the best candidate; going to the second position, choosing the best of the remaining candidates, etc.; finally, the last position, choosing from those who have not been selected earlier. The major problem with this process is that the order in which one chooses to go through the list of positions can make a large difference in how Sailors are matched to positions.

This aspect of sequential matching produces inherently poor matches. This is why it is essential to implement *simultaneous “optimization”* rather than *sequential matching* to assure that the best outcome is always achieved. We illustrate this with the following spreadsheet examples shown below, which show Sailors (columns) and positions (rows). Each cell is a “skill score” for the particular Sailor-position match, similar to the score used in JCMS. Assuming each Sailor is eligible for each position, the skill score takes into account factors such as rating, pay grade and NECs.

In Table 8 the highlighted cells illustrate the matches that would be made using a sequential approach. For example, Sailor 1 would match to Pos 4, a score of 84 is the highest in this column. Sailor 2 would match to Pos. 5. And so on. Summing the scores of each match gives an overall objective function score of 711 (higher scores reflect better matches).

Table 8
Sequential Matching

Sequential Matching Obj. Fn. = 711	Sailor 1	Sailor 2	Sailor 3	Sailor 4	Sailor 5	Sailor 6	Sailor 7	Sailor 8	Sailor 9	Sailor 10
Pos. 1	70	70	84	72	70	62	70	70	70	70
Pos. 2	35	50	35	35	36	35	50	34	35	35
Pos. 3	49	33	35	41	47	35	33	55	49	53
Pos. 4	84	67	67	72	81	67	67	86	84	91
Pos. 5	82	97	82	82	83	85	97	81	82	82
Pos. 6	70	70	84	72	70	84	70	70	70	70
Pos. 7	84	68	68	69	67	69	68	70	62	70
Pos. 8	66	58	58	58	70	57	58	59	64	59
Pos. 9	76	83	83	83	79	83	83	84	75	84
Pos. 10	65	71	71	70	68	71	71	69	63	69

For the optimized matching, by using a mathematical optimization algorithm (e.g., EXCEL Solver), one calculates the optimal Sailor-position match by consideration of all possible matches simultaneously, even those which are eliminated by early temporary

choices (see Table 9). Here the example shows that Sailor 1 is matched to Pos.7; Sailor 2 is matched to Pos. 2. Note that the Sailor 2-Pos. 2 match score is only 50 compared to the sequential match of Sailor 2 to Pos. 7 scoring 97. Interestingly, the sequential match for this one Sailor and position is far better; yet, it caused a ripple effect so that many other better matches for other Sailors could not take place because of this early match. The overall objective function score for the optimal match is 764, a definite improvement over the sequential approach score of 711. It is for this reason that whenever Sailor-position matching takes place that optimized matching should be used rather than sequential matching.

Table 9
Optimal Matching

Optimal Matching										
Obj. Fn. = 764	Sailor 1	Sailor 2	Sailor 3	Sailor 4	Sailor 5	Sailor 6	Sailor 7	Sailor 8	Sailor 9	Sailor 10
Pos. 1	70	70	84	72	70	62	70	70	70	70
Pos. 2	35	50	35	35	36	35	50	34	35	35
Pos. 3	49	33	35	41	47	35	33	55	49	53
Pos. 4	84	67	67	72	81	67	67	86	84	91
Pos.5	82	97	82	82	83	85	97	81	82	82
Pos. 6	70	70	84	72	70	84	70	70	70	70
Pos. 7	84	68	68	69	67	69	68	70	62	70
Pos. 8	66	58	58	58	70	57	58	59	64	59
Pos. 9	76	83	83	83	79	83	83	84	75	84
Pos. 10	65	71	71	70	68	71	71	69	63	69

It should be pointed out that the algorithm for calculating current on-board personnel versus pay grade and NEC requirements used by the current legacy requisition generation system, Enlisted Personnel REquisition System (EPRES), does *not* perform an actual matching of persons to positions (either in a sequential or optimized way). Rather EPRES, using several iterations, compares pay grades and NECs and tabulates shortfalls at the aggregate level and not position by position.

Person-to-Position Pilot

Navy MPTE leadership instituted the study of matching personnel to positions onboard Navy activities and reviewed several platforms with respect to their current manning. This study, called *Person-to-Position Pilot*, was conducted from January through March 2006, under the direction of the Enlisted Assignment Division, Navy Personnel Command (PERS-40). A pilot team was established including Manning

Control Authority (MCA) Pacific, PERS-40, Navy Manpower Analysis Center (NAVMAC), Enlisted Placement Management Center (EPMAC), Navy Personnel Research, Studies, and Technology (NPRST), and Space and Naval Warfare Systems Command (SPAWAR) Support Center. The stated purpose of the Interactive Detailing: *People-to-Position Pilot* was to “evaluate the possibility of using a requirements-driven position management strategy.” As part of the study, use case rules for matching were proposed and evaluated.

The pilot was based on three test units (USS McFaul DDG-74, USS Milius DDG-69, and USS Curtis Wilbur DDG-54) to test the ability to automatically place Sailors attached to the units into positions, based on the February 2006 Enlisted Distribution Verification Report (EDVR). Alternative approaches to match current-on-board (COB) to activity positions were developed and evaluated. Pay grade, rating, and NEC data were used for matching.

Person-to-Position Matching Rules (Proposed)

The *Person-to-Position Pilot* developed several proposed approaches, or use cases, for matching rating, pay grade, and NECs. These business rules provide alternative levels of adherence to requirements, starting out in Use Case 1 as very strict, exact matching, relaxing more and more with each subsequent Use Case. These proposed approaches are based on sequential matching which is dependent on the order of matching. Therefore, the results may not be repeatable, reliable, or accurate. However, the use cases illustrate complexity in performing matches based on two factors, pay grade and NECs, since matches across ratings are prohibited, under these proposed business rules. The proposed matching rules are specified in the five Use Cases below:

Use Case 1

- Match will be made by comparing Sailor’s actual rate and all earned NECs in Sailor’s inventory primary NEC (PNEC), secondary NEC (SNEC), tertiary NEC (TNEC), quaternary NEC (NEC4), quinary NEC (NEC5). In this case, if it is not an exact match, then there will be no match.
 - Distribution NEC (DNEC) may also be used for prospective gains.
- Business Rules
 - Sailors will be matched in the following priority:
 - Sailors currently on board with projected rotation date (PRD) greater than 6 months from current date.
 - Sailors listed as prospective gains to the command.
 - Sailors currently on board with PRD less than 6 months, but beyond current month.
 - Sailors with PRD of current month or with an expired PRD will not be matched.

- Sailors will be matched by rate first, and then matched to NEC skills.
- Sailors will use actual pay grade, not prospective pay grade when making the match.
- Sailors in pay grades E-1 to E-3 are considered the same pay grade. For Sailors in pay grades E-4 to E-9 will each be considered as separate pay grades
- For dual NEC positions, the Sailor must match both NECs or a match will not be made. Dual NEC positions will be matched before proceeding to single NEC positions.
- Tie breakers (more than one Sailor makes a match to a position)
 - Earned NECs will take precedence over DNECs.
 - Sailors with less total earned NECs will be matched before Sailor with more earned NECs.
 - If NEC tiebreakers above do not break tie, use Sailors with PRD closer to but greater than P6.

Use Case 2

- Use Case 2 will follow all rules from Use Case 1.
- The following additional rules will be added.
 - If a dual NEC positions are not matched on the first pass, then the PNEC alone will be considered for a match with all other single NEC positions.
 - If the PNEC is not matched in this run, then remaining unmatched Sailors may make SNEC requirement match.

Use Case 3

- Use Case 3 will follow all rules for Use Case 1 with amendments as listed below.
- The following additional rules will be added.
 - Once the initial pass is made for Dual NEC positions using UC1 rules, the Master (M), Journeyman (J), and Apprentice (A) structure will be used to make only Dual NEC matches:
 - Levels are: M = pay grades E-7 to E-9, J = pay grades E-5 to E-6, A = pay grades E-1 to E-4.
 - For the Master level the following priority will be followed based on the requisition for position:
 - E-7, E-8, then E-9
 - E-8, E-9, then E-7
 - E-9, E-8, then E-7.

- After the M–J–A Dual NEC pass is made, the Use Case 1 rules will be applied for all single NEC requirements with the additional rules from Use Case 2 added. (All unmatched Dual NECs positions will be reviewed as the Primary NEC only.)
- After this pass is made, M–J–A structure will be used to make matches for any vacant positions.
- Note: There is still no “ripple” match made in Use Cases 1-3. If a match is not made by pay grade (Use Cases 1, 2) or MJA (Use Case 3) and NEC, then there will be no match.

Use Case 4

- Use Case 4 will use the rules set forth in Use Case 3.
- The following additional rules will be used when all matches are complete in Use Case 3.
 - If there are any positions still unmatched after all runs are completed, then Sailors from the pay band above will be used to make matches.
 - Matches will be made by looking at the lowest pay grade in a pay band, then going up to the next pay grade. (A vacant Journeyman position would look at E-7s first, then E-8, then E-9. A vacant Apprentice position would look for E-5 first, then E-6).
 - Unmatched Master Sailors will not be allowed to fill vacant Apprentice positions.
 - Note: This use case adds a ripple up effect that should counter the impact of advancements.

Use Case 5

- Use Case 5 will use all of the rules set forth in Use Case 4.
- The following are additional rules for this Use Case.
 - If there are still vacant positions and unmatched Sailors at this point, then it will generally be due to shortage of inventory at the correct or more senior pay band, or a shortage of NEC skill sets. This Use Case will attempt to correct for NEC shortages.
 - In this case, unmatched Sailors will be compared to M/J/A and rate only, with no regard to NEC requirements of the position. Pay grade shall be used first, then MJA.
 - Once this pass is made, Sailors from the next senior pay band can be used to achieve a match as noted in Use Case 4, but without an NEC match.
 - No Master would be allowed to fill an Apprentice position.

Specifically note sequential matching is performed in the Use Cases above, and the order of matching is referenced. For example, for dual NEC positions, the Sailor must match both NECs or a match will not be made. The Use Case 1 sequential matching process specifies that dual NEC positions will be *matched before proceeding to single* NEC positions. Consideration of dual-coded NEC positions first is specified as a way to achieve a better matching outcome, avoiding poor early choices that impact downstream choices. This aspect of sequential matching is called the “ripple-effect;” early selections influencing later possible choices. Simple consideration of dual positions first does not avoid the problem of ripple effects. It may not improve matching; it may even make it worse. This shows the criticality of using optimization to perform the matches, providing accurate, reliable matches.

Scoring Rule for Skill Match Based on Weighted Factors

It is best to match Sailors to positions based on an objective scoring rule. The purpose of the scoring rule is to assign a single number between 0 and 100 to each Sailor’s overall skill match to a specific position. The desirable features of such a scoring rule are as follows:

- Easy to explain to sailors, commands, detailers
- Simple and fair
- Easy to implement and maintain
- Fast to execute, so as not to become a computational bottleneck
- Takes into account factors: rating, pay grade and NECs and future taxonomies characterizing required knowledge, skills and abilities
- Basic eligibility attained if achieving a specified score level

Factors going into a skill match typically include:

- Rating(s) or job type
- Pay grade(s) or pay bands
- NEC(s) or future taxonomies characterizing required knowledge, skills, and abilities

Pseudo-Code for Calculating Skill Match Score

Consider Use Case 1 above, described as possible algorithm for *Person-to-Position Matching Pilot*. This use case is the most stringent, requiring exact matching of rating, pay grade, and NECs. Eligibility is limited to those personnel currently onboard (with PRD greater than one month out) or a prospective gain. E-1 to E-3 are considered the same pay grade; E-4 to E-9 are treated as separate pay grades.

Given that a match will only be made by an exact match of rating, pay grade, and all NECs; the scoring rule weights for these factors can be considered equivalent. Basically, one must achieve a perfect score in order to “match.” Let indices *i* and *j* represent Sailors and positions, respectively. Initialize arrays: ratingmatch, pgmatch, necmatch to zero. Weighting factors for rating match, pay grade match, and NEC match are set for variables: wr, wp, wn respectively at one-third for each. See pseudo-code for Use Case 1 in Figure 1.

```

FOR i = 1 to NSailors BEGIN
  FOR j = 1 to NPositions BEGIN
    IF rating (i) = rating (j) then ratingmatch (i,j)=100;
    IF PG(i) <= 3 AND PG(j) <= 3 THEN pgmatch(i,j)=100;
      ELSEIF PG(i) =PG(j) THEN pgmatch(i,j)=100;
  Comment: Will only show case where Primary and Secondary NECs required
    IF PNEC(j) = ONEOF (EN1(i), EN2(i),EN3(i),EN4(i), EN5(i))
      AND
      SNEC(J) = ONEOF (EN1(i), EN2(i),EN3(i),EN4(i), EN5(i))
      THEN necmatch (i,j) = 100;
    skill(i,j)= wr* ratingmatch(i,j) + wp*pgmatch(i,j) + wn*necmatch (i,j);
    IF skill(i,j) ~= 100 then skill(i,j) = 0;
  Comment: Only exact matches: rating, paygrade, both NECs
  END;
END;

```

Figure 1. Pseudo-code for Use Case 1.

Under the Use Case 1 scoring rule, *necmatch* is either 100 or zero. There is no intermediate score for matching only one of the two required NECs or the rating or pay grade. Now consider Use Case 2, where the scoring rule should be adjusted to take into account lower scores for matching only PNEC or SNEC only. The Pseudo-Code example in Figure 2 shows the assignment of lower scores for matching PNEC and SNEC at 75 and 50, respectively. Again, assume ratingmatch, pgmatch, and necmatch are initialized to zero.

```

FOR i = 1 to NSailors BEGIN
  FOR j = 1 to NPositions BEGIN
    IF rating (i) = rating (j) then ratingmatch (i,j)=100;
    IF PG(i) <= 3 AND PG(j) <= 3 THEN pgmatch(i,j)=100;
      ELSEIF PG(i) =PG(j) THEN pgmatch(i,j)=100;
    Comment: Will only show case where Primary and Secondary NECs required
      IF PNEC(j) = ONEOF (EN1(i), EN2(i),EN3(i),EN4(i), EN5(i)) THEN BEGIN
        IF SNEC(J) = ONEOF (EN1(i), EN2(i),EN3(i),EN4(i), EN5(i))
          THEN necmatch (i,j) = 100; ELSE necmatch(I,j)=75; END
        ELSEIF SNEC(J) = ONEOF (EN1(i), EN2(i),EN3(i),EN4(i), EN5(i))
          THEN necmatch (i,j) = 50;
        If ratingmatch = 100 AND pgmatch =100
          THEN
            skill (i,j)= wr* ratingmatch(i,j) + wp*pgmatch(i,j) + wn*necmatch (i,j);
          ELSE skill (i,j) = 0;
        END;
      END;
    END;
  END;

```

Figure 2. Pseudo-Code for Use Case 2.

Note that Use Case 2 requires exact rating and pay grade match. (See Table 10) Columns represent Sailors, and rows represent positions. Note the primary and secondary NECs (labeled PN, SN respectively) required by the various Operational Specialist (OS) positions are shown, as well as the Sailors' earned NECs ,labeled Pri (primary), Sec (Secondary), Ter (Tertiary), Qua (Quaternary). Note the shaded area denotes Sailor-position ineligibility because of lack of pay grade match.

Table 10
Example NEC scores – Use Case 2

Sailor's Earned NECs														
		Qua									0310	9595		
		Ter				9575	9575		9595	0311	0318	0342	0310	
		Sec			0170	0342	0342		0310	0334	0310	0350	0350	
		Pri	0000	0310	0201	0318	0318	0326	0350	0324	0324	0319	0319	
PN	SN		OS3	OS3	OS3	OS2	OS2	OS2	OS2	OS2	OS1	OS1	OSC	
0310		OS3	0	100	0									
0310		OS3	0	100	0									
0342	0310	OS3	0	50	0									
0342	0310	OS2				75	75	0	0	0				
0318	0310	OS2				75	75	0	0	0				
0318	0310	OS2				75	75	0	0	0				
0324	0310	OS2				0	0	0	0	75				
0324	0310	OS2				0	0	0	0	75				
0319	0326	OS1									0	75		
0326	0310	OS1									50	0		
0326	0350	OS1									0	50		
0310		OSC												100

The skill score derivation for each Sailor-position match against the Use Case 1 business rules can then be used by the optimization algorithm in matching Sailors to position in a simultaneous manner. This process assures that issues related to sequential matching are avoided and the best possible match can be achieved. Note that the optimization constraints can be set so that only those matches will be made where the skill score is above 50 as in this example, or user specified. By using optimized matching, additional runs of sequential matches are unnecessary and ripple effects of early poor matches are avoided.

Now, consider pay grade match scoring methods. Use Case 1 and Use Case 2 require exact pay grade matches, illustrated by the scoring below in Table 11. The shaded areas show where eligibility is violated.

Table 11
Use Cases 1 and 2 pay grade scoring

		Sailor					
		E-1 to E-4	E-5	E-6	E-7	E-8	E-9
Position	E-1 to E-4	100					
	E-5		100				
	E-6			100			
	E-7				100		
	E-8					100	
	E-9						100

Now for Use Case 3, recall the following criteria for matching:

- Levels are: M = E-7 to E-9, J = E-5 to E-6, A = E-1 to E-4.
- For the Master level: The following priority will be followed based on the requisition for position.
 - E-7, E-8, then E-9
 - E-8, E-9, then E-7
 - E-9, E-8, then E-7

To represent these priorities in a scoring rule, see Table 12. Note that the pay grade score for an E-8 Sailor matching an E-7 position is 80 rather than a full 100 score for an exact E-7 match. An E-9 Sailor matching the E-7 position is awarded a pay grade score of only 60. Using this scoring approach, the optimization algorithm will prioritize the match of an E-8 Sailor to an E-7 billet over an E-9 Sailor to an E-7 position.

Table 12
Use Case 3 pay grade scoring

		Sailor					
		E-1 to E-4	E-5	E-6	E-7	E-8	E-9
Position	E-1 to E-4	100					
	E-5		100	100			
	E-6		100	100			
	E-7				100	80	60
	E-8				60	100	80
	E-9				60	80	100

Recommendation: Person-to-Position Matching Algorithm

The example skill matches shown earlier (GSM, FC, OS, and ET) each illustrate the complexity of matching skill using even just two factors: pay grade and NEC. Therefore, one recognizes there is not a simple, single formula that will accurately calculate skill score, with consideration for basic eligibility, for all positions across the Navy. With this in mind, consider the importance of basic eligibility.

Basic Skill Eligibility Criteria

Note that these criteria may vary by particular ratings, pay grades and/or NECs. These criteria include factors such as:

- Exact rating match or matching to a group of ratings
- Exact pay grade, pay band match or within a range of pay grades
- Exact NEC match, both primary, secondary, or combinations

Eligibility criteria can be handled using conditional coding; or a scoring rule can be applied with a user-specified cutoff value for eligibility.

As shown in Figure 2 only those Sailors who match rating, pay grade, and NECs are given a skill score of 100—a perfect match. All others are given a score of zero. Therefore, one would say that the eligibility cutoff is 100 to meet the requirements of Use Case 1. This is an example of using a scoring rule with a cutoff to record and determine eligibility.

Skill Match Quality or Score

For purposes of matching, a match to the primary NEC is better than a match to the secondary NEC, all else being equal. What is the quantitative difference between the possible matches? Is the primary NEC match twice as good as the secondary? What about pay grade differences—are these penalized in a quantitative way? A possible scoring rule may double the penalty for a difference by two pay grades versus one pay grade; or, perhaps the penalties are the same.

One must also take into account importance of factors such as pay grade versus NECs; matching to pay grade may be far more critical than NECs, especially for master-level pay grades. Tables 13 and 14 take into account matching pay grade at the Apprentice, Journeyman, and Master level; giving a higher score for closer pay grades. It also shows that dual NEC matches are given a higher score than a matching to only one of the required two NECs. Note that ratings must match exactly (i.e., basic eligibility). Note that shaded areas show where eligibility is violated; even though an NEC may match. Also, note that Sailor FCCS is a possible good NEC match to two positions: FCC with NEC 1332 and FCCM with NECs 1104, 1321. By weighting pay grade and NEC match equally, one can combine the two factors. In Table 15, FCCS has combined scores of 90 and 77.5 for FCC – 1332 and FCCM – 1104, 1321 respectively, based on equal weighting of pay grade and NEC. Suppose the pay grade weight is triple the NEC weight. (See Table 16)

Table 13
Use Case 3 NEC scoring

				1120	1130
			9502	1105	1130
			1332	1108	334
					1104
			FC1	FCC	FCC
				FCCS	
	1105	FCC		100	0
	1120	FCC		0	100
	1332	FCC	100	0	0
1104	1321	FCCM		0	0
					75

Table 14
Use Case 3 pay grade scoring

	FC1	FCC	FCC	FCCS
FCC		100	100	80
FCC		100	100	80
FCC		100	100	80
FCCM		60	60	80

Table 15
Use Case 3 Combined pay grade and NEC scoring
(equal weighting)

				1120	1130
			9502	1105	1130
			1332	1108	334
					1104
			FC1	FCC	FCC
				FCCS	
	1105	FCC		100	50
	1120	FCC		50	100
	1332	FCC		50	50
1104	1321	FCCM		30	30
					77.5

Table 16
Use Case 3 Combined pay grade, NEC scoring
(Weight: Pay grade triple NEC)

			1120	1130
		9502	1105	1130
		1332	1108	334
		FC1	FCC	FCC
	1105	FCC	100	75
	1120	FCC	75	100
	1332	FCC	75	75
1104	1321	FCCM	45	45
				78.75

Note that higher weighting of pay grade versus NEC added over ten points to the score for the Sailor FCCS matched to the FCCM position, from 77.5 to 78.75.

Assumptions Related to Matching Algorithms

Considerations in specifying a numeric algorithm for skill match needs to take into account the quality of the data sources: Activity Manning Documents (AMD) and the Enlisted Master File (EMF). It is important to assure the AMDs accurately represent operational unit requirements. The accuracy of Sailor data in the EMF is also of utmost importance.

We assumed in these examples that all pay grades (E-4 to E-9) are equally important; that all NECs are equally important. One note in Use Case descriptions, accommodations are made for combining pay grades into bands: Apprentice, Journeyman, and Master. Further specific pay grade substitutions are allowed in Use Cases 3, 4, and 5. The scoring rule for these use cases consists of multiple calculations developed for the specific applicable cases, as illustrated in the pseudo-code examples for Use Cases 1 and 2 and Tables 7–13. Most useful is the score itself, broken out into components, with explicit weighting values. If assumptions are changed, results are readily apparent in the score values for specific Sailor-position matches.

Skill Match Formula

As noted earlier, it is recommended that optimized matching be used when matching Sailors and positions, based on skill match, as well as other possible factors. The recommended skill match algorithm is based on a formula that weights the ingredient factors in terms of importance. The weights vary from 0 to 1 and add to 1 (i.e. are normalized). The factors which are considered are rating, pay grade (E-1... E-9) and NECs: primary and secondary for positions and the five earned NECs for the Sailor.

Even though there is no one-size-fits-all algorithm for the skill match calculation, there is a one-size-fits-all *formula* that tailors the algorithm based on the specifics of the position characteristics. First, it is essential that the skill match be interpreted as a score showing quantitatively the degree of the skill match of the Sailor to the specific position.

This score should be an objective score that decomposes into the weighted factors making up the components of the score. See general formula below, based on the assumption that ratingscore, paygradescore, and NECscore are independent, additive linear variables which explain variation in skill score, S :

$$S = \alpha \text{ ratingscore} + \beta \text{ paygradescore} + \gamma \text{ NECscore}$$

$$\text{Where } \alpha, \beta, \gamma \geq 0, \text{ and } \alpha + \beta + \gamma = 1$$

Using this general formula, one can modify the weighting on factors for rating, pay grade, and NEC matching so that the exact outcome is achieved in the overall match. A minimum score may be required to be ascertained as even eligible for a particular position. Similarly, algorithms which score each of these three individual matching factors (rating, pay grade, and NEC) can be characterized as complex formulations which take into account needed specificity. A particular factor (e.g., *paygradescore*) may be calculated using a detailed algorithm, based on exact match, closer matches, etc. Further, if, for a specific position, pay grade is not an important factor, γ , the weighting on pay grade score, may be set to 0. Alternately, for a specific position (e.g., a CPO position), perhaps, NECs are not as important as pay grade. Then, the weightings may be assigned (e.g., $\beta = .75$; $\gamma = .25$).

Person-to-Position Fit – Using Future Taxonomies and Refinements

Future taxonomies characterizing required knowledge, skills and abilities may be based on Occupation Information Network (O*NET) or similar structures. If adopted by the Navy, matching will be handled very similar to rating, pay grade, and NECs. These future constructs are organized in a taxonomy to describe knowledge, skills, and abilities related to work to be accomplished within the specific positions within the Navy. Converse, Oswald, Gillespie, Field, & Bizot (2004) discuss methods for matching individuals, based on a similar scoring rule, which accounts for multiple factors each of which are of specific importance relative to the matching. Job type and pay band would be used as alternative matching constructs to rating and pay grade. Then the score will be calculated:

$$S = \alpha \text{ JobType} + \beta \text{ PayBand} + \delta \text{ Skill}_1 \dots + \gamma \text{ Skill}_n$$

$$\text{where } \alpha, \beta, \delta, \dots, \gamma \geq 0, \text{ and } \alpha + \beta + \delta + \dots + \gamma = 1$$

The score, S , whether calculated using a future taxonomy or the legacy NEC constructs would then be used in the matching process, based on optimized slating, to arrive at the best possible matches among a group of positions and Sailors.

Refinements to the position to position match scoring rule may need to take into account other matches on board the unit. For example, an NEC or a specific skill-type requirement which is common across multiple positions may not be weighted as heavily if several Sailors on board possess this earned NEC or specific skill-type. On the other hand, if an NEC or specific skill-type requirement common across multiple positions is not currently met by any Sailor on board, then an additional weighting may be associated with this requirement.

References

- Converse, P., Oswald, F., Gillespie, M., Field, K. Bizot, E. (2004). Matching Individuals to Occupations Using Abilities and the O*NET Issues and an Application in Career Guidance. *Personnel Psychology*, 57, 2.
- Sea Warrior High-level Functional Requirements*. (1May 2006). Sea Warrior Requirements Office, Req Pro Revision #1.0091.*Job-Advertising and Selection System (JASS) Career Management System (CMS) Spiral 2 Functional Requirements*. (May 2005). DEVDOCTMPRSRS0001.003. Millington, TN: Navy Personnel Command.
- U.S. Navy, Manual of Navy Enlisted Manpower and Personnel Classifications and Occupational Standards, Volume II Navy Enlisted Classifications (NECs), NAVPERS 1806.
- Interactive Detailing: People-to-Position Pilot Project Management Plan, Navy Personnel Command, Requirements Management Office, Millington, TN, January 30, 2006.

Appendix

Glossary

AMD	Activity Manning Document
APMS	Assignment Policy Management System
ET	Electronics Technician
FC	Fire Controlman
GSM	Gas Turbine Systems Technician–Mechanical
HM	Hospital Corpsman
JASS	Job Advertisement and Selection System
JCMS	JASS-based Career Management System
MPTE	Manpower, Personnel, Training and Education
MOE	Measure of Effectiveness
NEC (DNEC)	Navy Enlisted Classification, Distribution NEC
OS	Operations Specialist
PRD	Projected Rotation Date

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